CHAPTER 2

LITERATURE REVIEW

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2.1 Conventional Wastewater Treatment Processes

Whichever treatment process is chosen, the plant will inevitably produce other wastes such as dry sludge for disposal to the environment in addition to the final liquid effluent. This can be solid waste that may be sent to landfill, such as pressed sludge, or a liquid sludge for off site disposal (Hester, 1995). Biological treatment, mainly represented by activated sludge processes has become the major treating method in dealing with both municipal and industrial wastewaters in developed nations. For instance, European legislation has recently required a larger proportion of wastewaters to be treated biologically prior to discharge. In developing nations such as China, secondary sewage treatment plants are being built rapidly throughout the country (Saby, 2002).

The biological filter was introduced during the latter part of the last century but, in 1913, a radical new process was developed which resulted in a four-fold reduction in the size of sewage-treatment plants. This new method was called the 'Activated Sludge Process (ASP)', and whilst biological filters are still in use, especially for small works, the activated sludge is now the dominant secondary treatment process and is the 'engine' around which modern treatment systems are constructed. For various reasons, ASP can be expected to continue. These reasons are that ASP plants can be expected to last at least 50 years, with large investment in such plants, a great many plants which are less than 20 years old, most such plants can be up rated without major difficulty to meet such new standards. Furthermore there is no reason to suppose that biological treatment will be superseded by better and cheaper methods in the near future. The other major factors that will influence the design in the next two decades will be requirements to limit release of the nutrients Nitrogen (N) and Phosphorus (P) in a very much wider range (Eckenfelder, 1998).

Raw wastewater delivered to a treatment works will contain appreciable amounts of heavier solids such as grit and large suspended solids. It is necessary to remove these at an early stage in the treatment process in order to prevent damage to mechanical equipments such as pumps and aerators, and also prevent the blockage of pipes and valves. The removal of these materials is known as preliminary treatment. It is a simple operation achieved by passing the influent through a series of screens or strainers. The alternative method is to pass them through a macerator and return them to the inlet flow of the works such that they are removed by primary sedimentation. After the majority of large solid removed, the wastewater still contains a high concentration of suspended particles, and these are known as settleable solids. A well-designed sedimentation tank can remove up to 40% of the BOD in the form of settleable solids. The advantage of this is that it reduces the BOD load to the next stage of treatment and thus permits smaller reactor sizes, with consequent lower power consumption. In addition, the reduced BOD loading results in a smaller surplus sludge production, which in turn allows the provision of smaller secondary sedimentation tanks.

The aim of secondary treatment is to reduce the oxygen demand of an influent wastewater to a given level of purification. A large number of biological unit operations are available to achieve the aerobic oxidation of BOD. These all have two essential features in common, in that a reactor is required to contain the organisms which will effect the BOD removal and a mechanism is required to ensure that there is always a residual oxygen concentration. All unit operations can be classified on the basis of their microbial population, into either fixed film or dispersed growth processes. In the former, the microorganisms are immobilized or attached to an inert support, which is maintained in contact with the inflowing waste. In the latter the microorganisms and wastewater are kept in intimate contact by mixing, the mixing apparatus also being responsible for keeping the suspension aerated.

The fixed film processes represent the oldest form of wastewater treatment system. It also led to the development of the trickling filters during the last 30 years, a modification of the process known as a Rotating Biological Contactor (RBC) is more popular (Daigger, 1992). A trickling filter is a reactor of rectangular or circular plan, which is filled with a permeable media. Wastewater is distributed mechanically over the media and percolates down the filter to collect in an under drain system at its base. A microbial film develops over the surface of the media and this is responsible for removal of BOD during passage of the waste through the bed. Traditionally, crushed rock or blast-furnace slag of diameter 25-100mm has been employed, but this has limited filter depth of 3.0m. More recently the development of lightweight plastic media has permitted filter depths of up to 12m to be exploited. These have proved particularly popular in the treatment of high-strength industrial wastes. The major advantage of trickling filters is that they are comparatively simple to operate and have very low running costs. In addition they are able to tolerate shock and toxic loads owing to the short contact time of the wastewater with the slime layer. The disadvantages, however are their land requirements are high and they can only provide a limited treatment efficiency.

Another variation in the ASP is called the oxidation ditches. They operate at very low loading rates, without the need for primary sedimentation. The absorption-bio-oxidation (A/B) process is a system comprising a two-stage activated sludge process. The aim is to maximize the production of sludge in the two reactors. This saves aeration costs, since oxygen is required only for oxidative processes. The increased sludge undergoing anaerobic digestion can be used for methane production. The process operates without primary sedimentation and is characterized by a separation of the first-stage sludge from that of the second stage, consequently two secondary clarifiers are required. The first stage has a high Mixed Liquid Suspended Solid (MLSS) and this means that the process operates frequently in a facultative anaerobic mode. The treatment efficiency is low. The major mechanism is that of absorption of organic material to the sludge floc. The second stage completes oxidation of the wastewater. It operates aerobically and with a high solids retention time (Horan, 1990).

2.2 New Technologies

In many countries there is a lack of a tight regulatory standard, which makes it unnecessary to tighten the control on plants. The enforcement of the effluent regulation is often quite inadequate. Many regulatory standards are not adapted to the needs of the receiving water. One of the obvious components, which should be seriously considered, is the nutrient discharge, which can cause eutrophication.

The only way to have a continuous improvement of water quality is not to use products containing harmful substances that you cannot control the waste they produce. Products, which contain substances that is harmful to the environment, should not be used at all (Palmgren, 1992).

The new approaches in relation to the removal of organic matter from water are designed to result in a higher effluent quality. A number of new technologies for the advanced treatment of wastewater have recently been developed. The oxidative cometabolic transformation by methanotrophs and by nitrifiers represents new approaches in relation to organic carbon. Cometabolism is a widespread process in nature, affecting the degradation of many naturally occurring compounds and numerous synthetic man-made compounds. It has been defined as the degradation of a compound by organisms that do not obtain energy or carbon for cell growth from the transformation, and hence require an alternative source of carbon and energy.

Cometabolism can bring about a rapid biodegradation of compounds that otherwise would be broken down very slowly, if at all, in the environment. Also, lower residual contaminant levels may be achieved by cometobolic treatment that could otherwise be attained (Miserez, 1999).

The role of advanced WWTP in wastewater reclamation and reuse is reviewed. Most of the current wastewater reclamation and reuse technologies are essentially derived from those used in water and WWTP. However, opportunities for adopting technological innovations are much greater for water reuse applications, because reclaimed water will have an economic value as an alternative water supply. Furthermore, advanced wastewater reclamation technologies, such as activated carbon adsorption, advanced oxidation, and reverse osmosis, can generate a water of much higher quality than conventional drinking water, and the product obtained is thus designated as repurified water. At present, the dominant wastewater reuse applications, worldwide, are irrigation of agricultural lands, parks and golf courses. However, there has been considerable progress in reclaimed water applications in the urban setting such as toilet flushing, cooling, fire fighting, and stream flow augmentation (Mujeriego, 1999).

A development of a cost-effective modified primary treatment method, which significantly increase the removal of both soluble and colloidal Chemical Oxygen Demand (COD) without resorting to the use of any chemical coagulant. It involves recycling a small portion of the primary sludge and then activating it to enhance its biosorptive and flocculent properties through 30-min aeration period. The aerated sludge is then brought into contact with raw sewage to induce rapid biosorption of soluble COD and flocculation of colloidal organic before the mixture is settled in a regular primary clarifier. In this treatment approach, the raw sewage is not subjected to aeration; thus the sludge aeration tank volume and the aeration energy requirements can be minimized. Through this modified approach with a 15% sludge recycle rate and 30-min sludge aeration, the COD removal efficiency is 43.9% higher than that of the regular primary treatment. This would result in a significant improvement of the primary effluent quality, or achieve a substantial reduction of organic loading to the secondary biological system (Huang, 2000).

Microbial strains, characterized by increased tolerance and ability to grow in metal bearing wastewaters, as well as, by effective metal sequestering capability by both active (bioaccumulative) and passive (biosorptive) processes, were tested as inoculum for metal laden wastewater treatment systems. Their capacity is to grow in metal bearing wastewater, using an easily available and inexpensive carbon source such as acetate. Two principal conclusions were drawn: (1) Growth was observed for all the strains examined suggesting that the strains can be acclimate to metals bearing wastewaters. (2) Solution pH increased from neutral to alkaline values during growth ($pH_{initial}$=7, pH_{final}=10). The later was observed systematically for all strains. Metal precipitation, due to the metabolically generated alkalinity is expected as a result. A mechanism of metal precipitation induced by the metabolically generated alkalinity, when acetate is used as carbon source, could be proposed as the main process responsible for the metals sequestering inside the moving bed sandfilter reactor (Remoudaki, 2003).

The most common wastewater treatment facility is the low-load activated sludge treatment plants, due to their enhances ability to remove nitrogen, the electrical consumption of aerators represents around 80% of the total consumption of the plant. Reduction in electricity costs therefore, is necessary and requires the management of the aeration unit without adversely affecting the quality of the effluent, which is highly dependent on the quantity of oxygen diffused by the aerators (Charpentier, 1996).

Biological treatment of organic matter has a long tradition in agriculture as a way of improving the quality of fertilizers. In aerobic and anaerobic processes, the organic matter is decomposed to a soil-beneficial substrate, while the content of nutrients is maintained. Today these technologies play an important role in the development of sustainable waste management strategies. Recent development has focused on efforts to increase methane yields as well as degradation efficiencies of various kinds of organic wastes. Combined anaerobic and aerobic processes, pre-treatments and co-fermentation techniques have been established to improve the decomposition process and thus to reach maximum biogas yield (Vorkamp, 2001).

A case study in Poland, whereby a largest Pulp & Paper producer chose to upgrade the existing WWTP with a new floating biological bed equipped with an advanced steering system. The new demands have been reached with an advanced steering system controlling three selective biological reactors operating in series and/or parallel. Each biological reactor is operating at specific conditions to decrease selected organic compounds. The new floating biological bed, FlooBed®, is an upgraded activated sludge system with floating carriers covered with a thin biological film. The FlooBed® reactor is a progress from fluidised beds and modified activated sludge plants.

The activated sludge plant as such has not been rebuilt. The improvement of the activated sludge process is that the wastewater now is saturated with oxygen and new micro-organisms are created before the entry to the existing activated sludge plant. The FlooBed® reactors are installed in a volume that is 50 % of the former activated sludge plant volume and the reduction of COD has increased from 51 to 90 % (Hansen, 1999).

The capacity and efficiency of the existing activated sludge wastewater treatment plant can be enhanced due to an expected future increase in wastewater flow and COD-load. For the case of an existing upper limit of COD discharges into the river, the COD reduction rate of the wastewater treatment has to be increased to a degree, which is unobtainable by biodegradation only.

Laboratory and pilot plant trials using a moving bed biofilm technique and an activated sludge treatment combined with ozone treatment and subsequent biofiltration have been performed with the aim to increase the COD reduction capacity and efficiency of the plant. The results show that the COD reduction capacity of the existing ASP can be increased by more than 100% by integrating a moving bed biofilm pre-treatment stage into the plant. In addition, improved sludge separation in the secondary clarifier was established. A special benefit of the ozonation plus biofilter treatment is a controllable COD reduction between 20 - 90% related to the outflow of the activated sludge plant. It is concluded that by integrating the investigated treatment techniques in the existing activated sludge plant the future increases in wastewater flow and COD-Load can be handled satisfactorily without increasing bioreactor volume (Kaindl, 1999).

Two different re-oxygenation techniques (aeration and hydrogen peroxide addition) were compared in respirometric experiments. As similar results were obtained in both cases, it was concluded that the addition of hydrogen peroxide does not modify the oxygen uptake rate of the biomass, under either endogenous or feeding conditions. Hydrogen peroxide alters neither the biomass metabolism nor the biodegradability of the tested substrates. The oxygen uptake rates obtained with the aeration system were often more scattered due to the adhesion of fine bubbles after the switch off of the aeration. Moreover, the transfer ratio of oxygen to the solution is faster in the case of hydrogen peroxide addition. The rate at which biomass takes up the dissolved oxygen from the liquid phase is actually directly linked to both the characteristics of the biomass and the quality of the substrate (Vuillemin, 2002).

As interactions between chemical precipitation and biological wastewater treatment are well known, biological phosphate removal should be considered for advanced nutrient removal. A combination of biological phosphate removal and chemical precipitation treatment is sensible and economic, when the precipitation step is used for removal of residual amounts of phosphate. The need for reliable removal of nutrients from wastewater is a result of water quality requirements embodied in legal and administrative regulations. 'Chemical precipitation" is a recognized and reliable process. Chemical processes are generally considered to be the addition of metal salts, lime or organic polymers. Apart from phosphate removal, their main applications are for improvement of purification capacity in respect of organics and bulking sludge countermeasures in ASP (Grunebaum, 1992).

In a thermophilic (55°C) anaerobic reactor, using three different reactor configurations, 70% COD removals were achieved in all reactors. The anaerobic hybrid reactor, composed of an upflow anaerobic sludge blanket and a filter, gave degradation rates up to 10 kg COD/m^{3}d at loading rates of 15 kg COD/m^{3}d and hydraulic retention time (HRT) of 3.1 hours. The anaerobic multi-stage reactor, consisting of three compartments, each packed with granular sludge and carrier elements, gave degradation rates up to 9 kg COD/m^{3}d at loading rates of 15-16 kg COD/m^{3}d, and HRT down to 2.6 hours. Clogging and short circuiting eventually became a problem in the multi-stage reactor, probably caused by too high packing of the carriers. The anaerobic moving bed biofilm reactor performed similar to the other reactors at loading rates below 1.4 kg COD/m^{3}d, which was the highest loading rate applied. The use of carriers in the anaerobic reactors allowed short HRT with good treatment efficiencies (Jahren, 1999).

In order to encourage practicing engineers to use modelling more extensively during the analysis of WWTP, the International Association on Water Quality (IAWQ), models were reviewed for suspended growth cultures and to produce one capable of depicting the performance of WWTP receiving both soluble and particulate substrates in which organic substrate removal, nitrification and denitrification were all occurring. In 1987 the IAWQ Task Group for mathematical Modelling for Design and operation of Biological WWTP introduced the Activated Sludge Model No. 1 (ASM1), which is a structured model. This allows simulation of the behaviour of nitrifying and denitrifying activated sludge systems, which treats primarily domestic wastewater. The activated sludge Model No. 2 (ASM2) was introduced by the IAWQ Task Group in 1995 as a further development of ASM1. ASM2 introduce phosphorus-accumulating organisms and allows the simulation of the behaviour of biological phosphorus removal (Grady, 1999).

2.3 Wastewater Characteristics

During the seventies the main source of many of the inorganic pollutants were outlets from industries. The most stringent demands were put on industry and they built many pretreatment facilities. After the seventies when the industrial wastewater quality was improved more attention has been paid to other pollutant sources. Then it was found that the main source of lead in municipal wastewater isn't industry but due to the lead content in petrol and rise in traffic (Palmgren, 1992).

The number of organic chemicals produced at the present time is almost overwhelming. In any manufacturing process, waste products are produced at every part of the process, from mining the raw materials, through the manufacturing process, to the disposal of the product at the end of its life cycle. Pollutants may be classified into several groups. The first are the nutrients, such as nitrate, phosphate, and dissolved organics. A second group included trace metals, such as chromium, lead, and arsenic. The third and largest group is the synthetic organics, which included pesticide, industrial by-products, and solvents. Organic chemicals may also be divided into two classes based on solubility or lipid partitioning. These are hydrophobic compounds, which concentrate in lipids (fats), and hydrophilic compounds, which concentrate in water (Hounslow, 1995).

Since this treatment plant involves an integrated approach, therefore careful studying need to be taken on the different characteristics of the incoming influent. The organic material present in wastewater acts as a food source for the bacteria in the Ammonia Syngas Plant; therefore, any significant change in the wastewater characteristics affects the growth of microorganism in the treatment system (Junkins, 1983). All types of organics and in organics should undergo a careful study to understand the safety and the toxicity of the incoming influents.

2.3.1 Heat Exchanger Wastes

The main heat exchanger wastes are from the cooling tower and boilers within the vicinity of the plant. The cooling water in a plant is typically used for process vacuum pumps, chillers, air compressors, air dryers, or emergency generators.

Cooling water will often contain a wide variety of chemicals. Typically there is a large amount of both dissolved solids and suspended solids. The water will also typically contain some sort of corrosion inhibitor and/or scaling inhibitor. Oxidants such as chlorine, bromine, or sodium hypochlorite are usually present as well. Wastes in this system are usually in the form of scale deposits in the warm water supply system. Cooling towers and condenser systems are very vulnerable to corrosion, scale and fouling formation due to the following:

- saturation of corrosive dissolved oxygen in the make up water
- galvanic corrosion caused by dissimilar metals in the system
- under-deposit corrosion caused by fouling contamination
- cycling up of minerals causing scale deposits
- introduction of air-borne contaminants causing fouling

- ideal breeding conditions for algae, fungi, bacteria, *Legionella*

Formation of scale deposits will result in a loss of cooling transfer efficiency, translating directly into increased cooling costs. Raw water contains varying amounts of mineral salts such as calcium, magnesium, iron and silica. When these minerals exceed their solubility point due to increased cycles of concentration, the minerals precipitate out of solution and produce scale-forming salts (Weber, 1996).

Air contains particles of dust and dirt of various kinds, (depending upon the local environment), causing recirculating water to become contaminated with a variety of materials. This creates fouling on the inside surfaces of condenser systems which can lead to under-deposit corrosion and loss of cooling transfer efficiency.

Since towers contain warm water, are open to sunlight, trap a variety of life forms and nutrient sources, they are perfect breeding grounds for algae, fungi and bacteria. Some of these forms circulate throughout the condenser system, while others attach themselves to convenient surfaces. Corrosion is frequently found beneath these deposits.

A boiler is a closed vessel in which water under pressure is transformed into steam by the application of heat. In the boiler furnace, the chemical energy in the fuel is converted into heat, and it is the function of the boiler to transfer this heat to the contained water in the most efficient manner. The boiler is also designed to generate high quality steam for plant use. A boiler must be designed to absorb the maximum amount of heat released in the process of combustion. This heat is transferred to the boiler water through radiation, conduction and convection. The major gaseous corrosive contaminants are removed through proper chemical and mechanical deaeration. Migratory iron, migratory copper and other contaminants such as calcium, magnesium and silica must be conditioned within the boiler itself. Excursions of calcium, magnesium and silica can create deposition problems within the feed water train.

Minimization of these contaminants prior to the feed water train is the most successful way of dealing with this problem.

Boiler deposits result from hardness salts, metallic oxides, silica and a number of other feed water contaminants that can enter the system. In industrial boilers, it is cost prohibitive to eliminate all forms of contaminants in a pretreatment system. A controlled amount of contamination passes into the boiler with the feed water. Minimizing the adverse impact of these contaminants is the role of the boiler water treatment program. External corrosion and formation of deposits from combustion gases contribute as wastes in boilers. The principal scaling and fouling ions are calcium, magnesium, iron and bicarbonate and carbonate alkalinity. Silica is also a potential foulant.

In a steaming boiler, both of these conditions are met. While the boiler water is raised to a high temperature, the concentration of the dissolved salts is also increased. As steam is produced, dissolved salts remain in the boiler and continue to concentrate. Some salts may be soluble in the bulk boiler water. However, the boiler water immediately at the tube surface is considerably hotter than the bulk boiler water. As steam bubbles form near the tube wall, the soluble salts remain with the boiler water. This creates a localized high concentration of salts, even though the bulk boiler water may be well below saturation levels. The precipitation normally formed under these conditions has a crystalline structure and is relatively homogeneous. As boiler systems have become more efficient, higher quality feed water has been required. Consequently, the scaling salts have generally been removed prior to injection into the boiler. As a result, the particulate contaminants such as iron and copper become greater problems.

The main purpose of blowdown is to maintain the solids content of the boiler water within prescribed limits. This would be under normal steaming conditions. However, in the event contamination is introduced in the boiler, high continuous and manual blowdown rates are used to reduce the contamination as quickly as possible (William, 1971).

2.3.2 Vinyl Chloride Material

The main wastewater in the VCM plant is the VCM itself. VCM is a hazardous material that needs to be treated in this WWTP. Till the early 1960s VCM was assumed to be low toxic and used as an aerosol propellant in some countries, especially in USA and Japan. In the mid 1960s the occurrence of a bone disease called acrosteolysis (AOL) in a very small number of PVC plant operators, especially engaged in cleaning PVC reactors, was found. AOL is a bone disease, which usually takes a form of a degeneration of bone in the tips of the fingers. In early 1974, B.F. Goodrich PVC reported to the National Institute of Occupational Safety and Health (NIOSH) the discovery of cases of angiosarcoma (ASL), a very rare form of liver tumor among workers of their PVC plant. And the possibility of relationship of this rare cancer and exposure of operator to high concentration of VCM were subjected to the most urgent theme of the world of PVC industry. Prior to the discovery of cases of angiosarcoma among workers of the B.F. Goodrich PVC plant, VCM has been already proven as an animal carcinogen by test for the purpose of reproducing AOL in rats. Accumulated VCM exposure of 288 ppm per year is the minimum value for occurrence of ASL. There is no case of ASL in operators who started working on PVC plant after the Occupational Safety and Health Administration (OSHA) in USA specified 1 ppm as the maximum average personal exposure at 1974. The VCM regulation for working condition of other countries,lies between 1 and 5 ppm (Saeki, 2002).

Ethylene Dichloride (EDC) is also another by product waste of the VCM plant. Moderate EDC exposure around 1 ppm corresponded to a significantly greater sister chromatid exchange (SCE) frequency than was the case for the low EDC exposure group. However, VCM exposure to similar level was not associated with increased SCE. It is concluded that EDC may cause genetoxicity at a relatively low level of exposure (Cheng, 2000).

Under the auspices of its Dioxin Characterization Program, members of The Vinyl Institute, have analyzed for potential polychlorinated dibenzodioxin/furan (PCDD/F) concentrations in PVC resins, treated wastewater effluent and EDC product at EDC, VCM and PVC manufacturing facilities in the U.S. and Canada. No 2,3,7,8-tetrachlorodibenzodioxin (TCDD) was detected in any sample analyzed under the program to date. Trace concentrations (low pg/g) of PCDD/F were detected in only a few samples of PVC resins and EDC product. Treated wastewater contained low ppm concentrations of PCDD/F results show that the contribution of EDC/VCM/PVC manufacturing via these media constitutes substantially less than 1 percent of the estimated annual U.S. Dioxin releases to the environment (Carrol, 1998).

In 1971 there were evidence of vascular disturbance known as acro-osteolysis, Reynauds syndrome and scleroderma were all associated with exposure to VCM. These diseases were characterized by symptoms such as increased sensitivity to cold, changes in skin color and thickness, change in bone formation and the shape of the digits. These findings led to rapid and important changes in the details of PVC manufacturing. Therefore, major hazards associated with the monomer have been contained and PVC has resumed its natural growth pattern (Brydson, 1989).

2.3.3 Storm water Runoff

The runoff from rainfall, snowmelt, and street washing is less contaminated and therefore receives little or no treatment before being discharged into storm sewers or combined with the municipal wastewater for delivery to the WWTP. Storm water runoff, particularly in cities, contains dust and other particulates from roads, leaves from trees, grass cuttings from lawns and parks, and fallout from air pollution. The concentration of these contaminants is highest when they are first flushed into the treatment plant during the early stages of runoff and then decreases as the rain continues (Henry,1989).

Urbanization and the consequent increase in impermeable surfaces and changes in land use have generally resulted in increases in the rate and volume of storm-water flows due to the decrease in infiltration capacity resulting from the construction of impermeable surfaces over topsoil. Urban drainage practice in the past has been based on the philosophy of conveying peak flows of municipal wastewater and storm runoff away from the urban areas as quickly as possible. The resulting improvement in urban drainage systems and watercourses, and associated developments on flood plains, have resulted in downstream flooding and heavy pollution of receiving waters.

Pollution of storm water results from the contamination of rainwater through contact with various substances from the time of its origin in the atmosphere until the moment of its discharge into a receiving watercourse. The storm water acts as the carrier medium for the various pollutants of concern and, in addition to transporting these substances, the wastewater provided an environment under which transformation process occur (Andoh, 1994).

Urban storm water runoff is on of a significant source of pollution for many water bodies. The many varieties of pollutants such as wash off from road surfaces, parking areas, vehicles and building materials. Effects on receiving waters include oxygen depletion, eutrophication, species stress and toxicity. Suspended solids and heavy metals are high levels of many pollutants found (Davis, 2001).

2.4 Chemical Processes In Wastewater Treatment

The common inorganic constituents of wastewater include:

- Chlorides and sulphates. Normally present in water and in wastes from humans.
- Nitrogen and phosphorus. In their various forms (organic and inorganic) in wastes from humans, with additional phosphorus from detergents.
- Carbonates and bicarbonates. Normally present in water and wastes as calcium and magnesium salts.
- Toxic substances. Arsenic, cyanide, and heavy metals such as Cd, Cr, Cu, Hg, Pg, and Zn are toxic inorganics which may be found in industrial wastes.

In addition to these chemical constituents, the concentration of dissolved gases, especially oxygen, and the hydrogen ion concentration expressed as pH are other parameters of interest in wastewater (Henry, 1989).

Most of the nitrogen in the wastewater is in the ammonia form, and this passes through the off spec tank, as well as, the Equalizing Tank virtually unaltered. In the aerobic zone, the sludge age is such that almost complete nitrification takes place, and the ammonia nitrogen is converted to nitrites and then to nitrates. The nitrate-rich mixed liquor is then recycled from the aerobic zone back to the first anoxic zone. Here denitrification occurs, where the recycled nitrates, in the absence of dissolved oxygen, are reduced by facultative bacteria to nitrogen gas, using the influent organic carbon compounds as hydrogen donors. The nitrogen gas merely escapes to atmosphere. In the second anoxic zone, those nitrates that were not recycled are reduced by the endogenous respiration of bacteria. In the final re-aeration zone, dissolved oxygen levels are again raised to prevent further denitrification, which would impair settling in the secondary clarifiers to which the mixed liquor then flows.

Nitrification is one of the most difficult problems associated with the treatment of any industrial waste stream that requires further addition of key nutrients such as N and P. Most operators assess whether the nutrient addition has worked by analyzing the effluent either continuously or daily for Ammonical Nitrogen and Phosphate. The only solution is to accurately control the addition of nutrients to the feed stream using a combination of on-line respirometry and continuous analyzers for phosphate and Ammonical Nitrogen. A suitable control regime would gradually increase or decrease the dosage of nutrient based on the respirometric data being generated. Should the instrument detect a high load entering the facility it would automatically recommend that the nutrient dosage be increased pro-rata to match the load, only reducing the ratio when the load drops or is partially diverted to a buffer facility (Pocernich,1997).

In industrial wastewater, especially from food industry, the concentrations of the organic compounds are usually high, whereas the contents of nitrogen and phosphorus are often low. For the aerobic treatment, the addition of nutrients to the industrial wastewater can be required. For ecological and economic reasons, this nutrient addition must be kept to a minimum. Unintentional nitrification and denitrification lead to an additional demand of nitrogen and should therefore be avoided at such plants. Monitoring the NH_3 concentration can control N dosage. If the control procedure also considers the N/COD ratio in the raw wastewater (including the N dosage) and the organic sludge load of the last couple of days, very low effluent concentrations (NH_4-N in the range of 0.3–0.5 mg/l) can be achieved and the nitrogen dosage is low. If there are periods with N in excess, too, a minimum nitrification capacity has to be maintained by means of nitrogen addition in periods of deficiency. A control procedure for phosphorus addition is to keep a fixed P/COD-ratio in the raw wastewater (including P dosage). The phosphate concentration is monitored in order to limit the maximum phosphorus dosage. Following this procedure, considerable savings of phosphorus have been achieved, keeping very low effluent concentrations (average total phosphorus <0.3 mg/l) (Prendl, 2000).

Polymer application in industrial wastewater treatment has become very important in recent years due to the increased pollutant removal efficiencies, easier sludge disposal, economy in chemicals consumption, etc. Polymers may either be used as coagulants or as coagulant aids for the aggregation of colloidal particles (Turkman, 1991). A polymer is a large molecule built up by the repetition of small, simple chemical units. In some cases the repetition is linear, much as a chain built up from its links. In other cases the chains are branched or interconnected to form three-dimensional networks. The repeat unit of the polymer is usually equivalent or nearly equivalent to the monomer, or starting material from which the polymer is formed (Billmeyer, 1984). Chemicals responsible for particle destabilization are termed coagulants, and the process is termed coagulation. Different chemical coagulants can react in different ways. Depending on the conditions under which they are used, some materials can function either as primary coagulants or as adjuncts or aids to another primary coagulants. The polyelectrolytes, when serving as coagulant aids act to reduce the stability of colloidal systems and facilitate their coagulation (Weber, 1996).

In water treatment, anionic polymers are only rarely effective when used alone, and they are usually added in conjunction with traditional flocculants such as aluminum and iron salts. The main effect seems to be the formation of larger and stronger hydroxide flocs. Cationic polymers are sometimes used as primary flocculants in water treatment, where they can be effective in extremely low concentrations, depending on the turbidity of the water. Anionic polymers are not usually effective in effluent and sludge treatment. This may be due to the presence of natural anionic polymers present in biologically treated wastes. Cationic polymers are widely used in sludges treatment to improve dewaterability. Added cationic polymer and the natural anionic material present enmeshes the larger sludge particles to give a structure which is easily dewatered In this application high molecular weight cationic polymers are much more effective than those of low molecular weight (Gregory, 1983).

The volume of incoming wastewater and its quality will influence sludge production. Within the treatment plant, sludge is produced by primary sedimentation, by biological treatment processes and by chemical processes. Sludge production by biological treatment processes will depend on the organic load of the plant but also on the type of the process used. For example extended aeration processes give very low sludge production rates, due to auto-oxidation by microorganisms. Similarly a chemical precipitation depends on the dosage and type of the coagulant added as well as the volume of the wastewater (Katsiri, 1998).

Jar testing can be used effectively for the selection and/or determination of coagulant dosage, coagulant aid selection and dosage, sequence of chemical addition and optimum pH of coagulation. Jar test which determines the proper coagulant dosage, continues to be one of the most effective tools available to a WWTP. The purpose of the jar test is to use the results that it produces to effectively optimise the performance of the plant. The finished water quality and chemical usage cost depend on the proper application of chemicals to the raw water entering the treatment plant (Tillman, 1996).

Addition of chemicals and modifications of aeration tank diffuser had improved plant effluent quality. The City of Los Angeles USA Hyperion Treatment Plant implemented high rate air activated sludge operation and chemical addition to improve their treatment plant quality. Chemicals (ferric chloride and anionic polymer) have been added to the wastewater prior to primary treatment to increase SS removal efficiency from 60% to 85% and BOD_5 removal efficiency from 25% to greater than 50%. The activated sludge aeration system was converted from coarse bubble diffusers to a full floor grid flexible sheath membrane medium bubble diffuser system. It is suspected that this resulted in an oxygen transfer efficiency increase from 4.5% to 9% (Shao, 1992).

2.5 Aeration And Biomass Activity

Biological treatment processes fall into two large categories: fixed film systems and suspended growth systems. Here the plant uses the suspended growth systems whereby the biological growth mixes with the wastewater. Biological reactors, which are used for the secondary treatment of sewage, are primarily aerobic and therefore require an oxygen input. Oxygen is normally introduced as air at the base of a reactor through diffusers fed from a compressor. The efficiency of the diffusers determines the rate at which oxygen is transferred to the reactor liquor affecting the size of compressor required, energy requirement and operational cost of the system. The performance of diffused-air systems is determined by temperature, reactor geometry, submergence depth, size of bubbles produced, and airflow rate. The size of the bubbles determines the overall oxygen-transfer rate, and it is widely accepted that smaller (fine) bubbles provides better oxygen-transfer rates than larger (coarse) bubbles rising through water (Hodkinson, 1998).

The aeration systems perform the function of introducing oxygen into the aeration tank so that aerobic treatment of wastewater can proceed; at the same time a sufficient degree of turbulence must be created so that the settling out of the sludge suspension is prevented, an intensive materials transfer between the sludge flocs and the liquid being treated is encouraged and concentration surges are balanced out by the general dilution effect for incoming wastewater. There are a multitude of different types of aeration system and often several variants of any particular system. In addition, the aeration system influences the performance of the organisms by the degree of turbulences generated. Micro turbulence affects the nature of the reactor and the circulation pattern prevailing, while the macro turbulence governs the floc size and hence the area available for mass transfer between the sludge flocs and the liquid. The choice of a particular aeration system will be based on a number of different factors, such as economy of oxygen supply, equipment costs, the demands of tank geometry and hence the type of construction, the cost of service and maintenance and not least the effects on the environment due to factors such as noise, aerosol formation or foam build-up (Hanel, 1988).

The plant used for the purpose of this study, uses the mechanical aeration systems that use sparge rings to release air directly into the mixer. The size of the air bubbles produced directly affects the system efficiency – the finer the bubbles, the higher the efficiency levels that can be achieved (Drinan, 2001).

Classically used in activated sludge domestic WWTP, aerobic biological reactions are now a realistic solution for the treatment of industrial wastewaters. Because the effluent flow rates are generally high, large volumes, such as lagoons, are considered in order to reach the residence times, which are needed to obtain the required degradation performance. The methodology has been developed which allows best fitting between the biological reactions and the hydrodynamic behavior of the lagoon. Some of the main points are thus the technological choice and the scaling up of the aeration system, parameters which lead to the economical aspects of the process: investments, consumed energy and daily cost.

In order to optimize the process, it is necessary: -

- To determine the oxygen demand, which is generally experimentally obtained through biodegradability test (batch cultures),
- To define the optimal hydrodynamic structure which has to be realized inside the lagoon and the structural distribution of oxygen demand,

- To know the real performances of the available aerators. They are generally deduced from experiments realized with the industrial scale devices, but in study basins, which have sized and shapes very different from the real application site. Furthermore, the characteristic of the overall flow structure in the lagoon requires a specific attention because it must not only avoid having settlement areas but also maintain in each points and at any time the optimal physico-chemical environment for the microorganisms in order to obtain the expected metabolism. Such a flow is then very often quite different from the one, which exists in the study basins (Fonade, 2002).

Biodegradability of organic substances is the degree of the changes in physical and chemical characteristics and molecular structure of organic substances under degradation by microorganism. The aerobic biodegradability of organic substances can be affected by the changes of one of the following factors during the processes: (1) removal rate of organic substances; (2) the amount of oxygen consumption; (3) end products; and (4) the activity of microorganism (Jiang, 2002).

Since most industrial wastewaters fluctuate in flow rate and/or pollutant concentration with time, equalization is required to dampen these fluctuations and maintain stable process operation. The equalization basin should be completely mixed and can be operated in either a constant volume (variable outflow) or variable volume (constant outflow) mode. In industries subject to spill events and/or periodic shock loads, a spill basin should be provided to divert the influent wastewater flow when the concentration exceeds a predetermine value (Eckenfelder, 1998).

When the aerobic treatment of wastewater is considered, the scale-up of the aeration system is one of the most important problems to solve because of its consequence on the economical merit of the chosen process. When the oxygen is supplied only to a very small part of the volume of the broth (heterogeneous aeration), the main parameter is the amount of oxygen that is available for microorganism consumption in non-aerated regions (Fonade, 2001).

If the load is quite varied, then sizing the aeration system is difficult. In any activated sludge system the aim of the process is to convert soluble organic material together with some inorganic chemicals into biomass, water and carbon dioxide. The speed of this process depends on the biomass active components, temperature and nature of the feed material (waste). Conventionally the Mixed Liquor Suspended Solids (MLSS) has been considered to be the best guide to the actual level of active species.

2.6 Organic And Inorganic Components Of Wastewater

The average level of the Dissolved Oxygen (DO) concentration and the respiration rates will have a significant impact on the floc formation. Filamentous growth is strongly influenced by insufficient concentrations of dissolved oxygen or substrate. The total mass of sludge will depend on the growth rate of the organisms, which in turn depends on the DO and substrate levels. In a suspended system mixing is crucial. Using fine bubble or coarse bubble systems combines the needs for mixing and for DO supply. The mixing has to be sufficiently good so that the oxygen and the substrate will have a chance to penetrate the floc. On the other hand, too much mixing towards the outlet, when flocs are being formed, may prevent a good floc formation. Since the DO saturation concentration depends on the partial pressure of oxygen, the driving force for oxygen transfer can be significantly increased. Sometimes pure oxygen can be added in conventional air systems to improve the DO of the system under extreme load situations (Olsson, 1999).

Diffused aeration is used for various wastewater and sludge treatment processes. The oxygen requirements for these processes vary from as low as 0.1kg O_2/m^3d for slow processes (for example, extended aeration) to as high as 5 kg O_2/m^3d for high rate industrial WWTP and for aerobic sludge stabilization. The amount of air needed to satisfy oxygen requirements depends on the design parameters of the aeration system: diffuser pore or hole size, geometric parameters of the diffuser assembly, their location in the aeration tank, the shape and size of the tank, air-flow rate, physicochemical properties of the aerated liquid, and the DO concentration in the liquid. All these influenced the treatment efficiency of the WWTP (Khudenko, 1983).

The amount of DO required for treating a wastewater will depend upon the oxygen demand of the micro-organisms in the sludge, which are biochemically oxidizing both carbonaceous and nitrogenous substrates. It will also be affected by the loading rate of the sludge, which will change the endogenous respiration rate (Boon 1998). Even though enough oxygen is supplied, only a fraction of the amount supplied can be absorbed and become available to the microorganisms. The oxygen transfer efficiency is generally lower than the aeration tank mixed liquor than it is in the clean water. It can also decrease with the time of service due to the continuous fouling of the diffusers in the diffused air system. The fouling is dependent upon the cleaning frequency of the diffusers. Diffuser fouling can be due to the deposition of airborne particles on the inside surfaces of the diffusers and inorganic precipitates, as well as the accumulation of biological slime on the wetted surface of the diffusers (Eckenfelder, 1998).

The transfer of oxygen from a gaseous form to a dissolved form takes place within a time scale of 15-30 minutes. A change in airflow rates therefore does not immediately affect the dissolved oxygen concentration in the aerator. The respiration rate may change within minutes due to changes in substrate loading or toxic inputs. Mass transfer is the movement of a component between two phases. The notable example in aerated ASP is the transfer of oxygen from the air into the water so that it can be utilized by the biomass. In principle, the oxygen must move from the bulk air to the water surface, dissolve in the water, and then move from the surface into the bulk liquid. (Olsson, 1999).

The BOD is one of the simplest biotests of water analysis. This test is widely applied to define organic water pollution and to control the performance of WWTP. Generally, BOD is standardized by the measurement of oxygen consumption on five days (BOD_5), at $20^{O}C$ and in the dark. Utilization of BOD_5 as an evaluation method of the biodegradability of domestic wastewater and of the performance of WWTP is widely accepted. It is, however, noted that standard domestic wastewater has generally constant composition and rarely contains compounds or factor inhibiting biodegradation. In contrast, in the case of industrial effluents, the presence of many different inhibitory substances, the infinite number of possible mixtures and the high variability of chemical conditions necessitate an evaluation of the BOD_5 in order to test the suitability oft his approach for the predictive biodegradability characterization of industrial wastewaters.

This fact leads to two risks when BOD_5 is used to evaluate biodegradability of wastewaters containing inhibitors, first the microbial populations of domestic WWTP can be affected because BOD_5 values of industrial effluents do not express the real biodegradability of these effluents. Toxic substances can be complexed with organic substances coming from others rejected wastewater generating at the entry of the industrial biological treatment plant, a greater BOD_5 than estimated. Ecosystems can be affected because microbial populations of domestic wastewater treatment plants oxidize complexed substances with liberation of toxicants. In industrial effluents, the organic matter can mask toxicants. However, if the organic matter suffers a subsequent oxidation by a biological system, toxicants can then be released, reaching and affecting (if adsorption on sludge does not occur) natural waters. On the other hand, BOD_5 of an industrial effluent containing a high amount of biodegradable organic matter can be inhibited by different factors as toxicity, lack of nutriments, absence of adapted microorganisms, etc. In this case, it could be wrongly concluded, from a low observed value of BOD_5, that there is very little amount of biodegradable substances. But in drainage systems, dilution phenomena suppress these inhibitory factors and the real concentration of biodegradable organic matter reaching the biological treatment plant is actually higher than presumed (Hufschmid, 2003).

Relationships between major parameters, such as soluble BOD_5/COD; may also be interpreted as simple but useful indexes of treatability. BOD_5, although not recommended individually as a substrate parameter, may be regarded as a crude index of relatively easily biodegradable organic matter and may be beneficial in combination with COD, as the BOD_5/COD ratio. For an industrial wastewater with a ratio of 0.1 (BOD_5 = 100 mg/L; COD = 1000 mg/L), the following comments may have varying degrees of validity: (a) the wastewater contains very slowly biodegradable organics; (b) the majority of the organic matter is residual (non-biodegradable); (c) the wastewater also contains compounds with inhibitory effects, such as heavy metals, toxic organics, etc.; the biological treatability may be expected to greatly improve when these inhibitors are identified and removed; (d)biological treatability requires an acclimation period; in this case, the value of BOD_5 is meaningless; (e) BOD_5 result or both BOD and COD results are wrong (Orhon, 1999).

The bacteria requires N and P in order to affect metabolism and removal of organics in the process. In addition, trace levels of other micronutrients are required to assure good floc formation. To assure adequate nitrogen and phosphorus for BOD removal is to provide a nutrient mass ration of 100:5:1 (BOD: N: P). A higher ratio will reduce the rate of BOD removal and promote filamentous growth. The rate of degradation in SBR (Sequencing Batch Reactors) could be increased by the addition of glucose as a supplemental carbon substrate (Hess, 1993).

Cell respiration had an enhancing effect on oxygen transfer rates. The higher the specific Oxygen Uptake Rate (OUR)sp, of the new wastewater solids, the greater the enhancement of cell respiration. In the absence of respiration, the physical presence of solids retarded oxygen transfer because of a blocking mechanism resulting from the lower oxygen permeability in the solids layer accumulated around the bubbles. Wastewater modifications are also important to the oxygen transfer capability. The changes in wastewater contents of surface-active material and the removal of mineral salts during processes are two important factors which contributes to the OUR (Sundarajan, 1995).

Eutrophication can be defined as the process of enrichment of natural waters by the ingress of nutrient. Nitrogen and Phosphorus are the main nutrients involved, and the rate of enrichment of natural waters has tended to be accelerated by human activities; for example widespread use of chemical fertilizer, discharge of effluents into watercourses in increasing volumes (Gray, 1985). WWTP are important point sources of nutrient to rivers and sometimes are the dominant source (Pocernich, 1997). N and P are the main two elements referred to as nutrients. The reason is that these two elements are considered to be the limiting nutrients fro the growth of algae in eutrophic surface waters.

Current interest in watershed-based approaches to addressing water quality problems including eutrophication caused by excessive nutrient loading is high. Excessive P loading leads to algae growth, oxygen depletion, submerged aquatic vegetation and water clarity problems. These problems will give a negative effect on the commercial value, recreational and aesthetic value of an associated water resources (Schleich, 1997).

The WWTP studied have very high chloride content. High salt or chloride content in the wastewaters can pose certain problems in treatment systems particularly on biological units. The chloride level has adverse impact on MLSS of the system. As the chloride concentrations increases, the MLSS at the steady state drops. Generally, bacteria retain their water under high osmotic stress by production of compatible solutes, e.g., glycerol, sorbitol, or betaine. A high ionic strength solution raises the microbial activities in order to retain cell moisture within cytoplasmic membrane, thus, higher oxygen consumption by the microorganism was apparent. In addition, as the accumulation of salt within the cells increased, the oxygen demand increases as well. In other words, under osmotic stress, most uptake oxygen was used to struggle for survival rather than for substrate degradation and the accumulated salt in cells degraded the oxygen utilization efficiency.

The magnitude of COD removal efficiency declines as the chloride in the feed increased. After recovery, the system performance returns to almost the same level as that before chloride shock, especially in the system which had been acclimated with sodium chloride by pre-inoculation and/or perhaps self-adaptation of the microbial (at high salt dosed). There is also a tendency for the system without inoculation of salinity-accumulated bacteria to exhibit MLSS decreasing trend with higher sodium chloride doses. Cell washout seemed to be the possible explanation for this phenomenon. However, with the acclimated system, this effect was diminished (Panswad, 1999).

2.7 Activated Sludge Process (ASP)

The ASP was originally developed to intensify the natural process of self-purification, which occur in the aquatic environment, by bringing together wastewater and a high concentration of microorganisms in an aeration tank.

Currently the most widely used biological treatment, the ASP recirculates part of the biomass as an integral part of the process. This allows relatively short acclamation processes for microorganism adaptation to changes in wastewater composition, and a greater degree of control over the acclamation bacterial population. The ASP removes BOD_5 and suspended matter through aerobic decomposition (Drinan, 2001).

Biosorption expresses the transport of organic matter from the wastewater to the activated sludge followed by retention within the flocs. A fraction of the organic matter is transferred between the aqueous phase and the activated sludge flocs within a few minutes. On an average, 45% of the non-settleable (i.e., colloidal and soluble) fraction of the wastewater was removed during this short contact. Fractionation of the non-settleable matter into a colloidal and a soluble fraction revealed that steady state was obtained after 20 and 40 min, respectively. One can assume that steady state obtained for soluble matter is delayed because of its diffusion into the floc matrix. This diffusion becomes a limiting step of soluble organic matter removal. Colloids do not penetrate into the matrix because of their size, and may then be trapped very early in the outermost part of the floc. In some cases, desorption of organic matter from the flocs was observed. The release of colloidal matter was shown to be responsible for this phenomenon, whereas the soluble fraction was always transferred from the wastewater to the activated sludge flocs (Guellili, 2001).

In a complete mix ASP, the wastewater and the return sludge are introduced into the aeration basin at multiple points to facilitate their rapid blending with the basin contents. The objective is to maximize equalization of the influent load within the aeration basin. Another advantage of a complete mix process is that the oxygen uptake rate is equalized throughout the basin, thus permitting uniform spacing of the aeration equipment.

When an ASP is being assessed, there are a number of criteria that are critical in judging performance. These include the stability of pollutant Carbon (C) and N removal, aeration efficiency, sludge settlement and lastly the sludge production (Stokes, 2000). The ASP system include an aeration basin followed by a settling tank. The aeration tank received effluent from primary clarifier, as well as, a mass of recycled biological organisms from the secondary settling tank. Aeration tanks provide the required detention time, which depends on the specific modifications. Detention time ensures that the activated sludge and the influent wastewater are thoroughly aerated, leaving no dead spots. Modification of a conventional activated sludge process by inserting a sludge holding tank in a sludge return line forms an oxic-settling-anaerobic (OSA) process that may provide a cost-effective way to reduce excess sludge production in activated sludge processes. It has also been found that the sludge decay process in the sludge holding tank may involve the reduction of the cell mass (Guang, 2003).

The DO in the aerobic part of an activated sludge process should be sufficiently high to supply to the microorganisms in the sludge. On the other hand, an excessively high DO (which requires a high airflow rate) leads to a high-energy consumption and may also deteriorate the sludge quality. Both for economical and process efficiency reason, it is of interest to control the DO (Lindberg, 1996).

With the growing applications of ASP, huge amount of solids waste, namely the excess sludge is generated daily as the byproduct of the transformation of dissolved and suspended organic pollutants into biomass and evolved gases (CO_2, CH_4, N_2 and SO_2). The treatment and ultimate disposal of excess sludge are expensive, which usually accounts for 30-60% of the total operational cost in a conventional activated sludge treatment plant. This cost will be increased due to increasing restrictions on the sludge disposal. In addition to the cost, the ultimate disposal of the sludge by landfill and/or incineration is facing difficulties in densely populated cities to locate suitable sites. Therefore, critical thinking is needed in order to reduce excess sludge production cost effectively (Saby, 2003).

An ideal sludge should contain only well settleable flocs that will give good thickening properties. Thickening is the mechanism involved in the concentration gradient of settled particles below the sludge blanket level. In reality the floc is very diverse. It may contain dispersed small flocs that will hardly settle at all. Such flocs will become part of the unexpected wasted sludge via the effluent. Too many filaments will create large settleability problems. A small fraction of filaments may in fact be favorable for the clarification. They may create bridges between the flocs. Such a structure can then filter the dispersed flocs so that the clarifier effluent actually improves. Too many filaments will obviously create sludge bulking.

Sludge is a rather concentrated dispersion of particles, usually with a wide range of particle sizes. The interactions of these particles, both with each other and with soluble constituents, are of great importance in determining the properties of the sludge. Larger particles are subject to a greater gravitational force and have no greater thermal energy than sub-micron particles, so they settle more rapidly.

In dilute sludges, such as activated sludge, metabolic activity will determine the rate of substrate utilization, the quantities of oxygen required to maintain aerobic conditions, and the quantities and composition of excess sludge for subsequent sludge handling processes. The important elements required for cell synthesis come from a number of sources such as carbon – CO_2 (photosynthesis), carbohydrates, proteins and fats; nitrogen – proteins, NH_3 and NO_3; sulfur – proteins, sulfate ions and phosphorus (PO_4). In addition, trace elements are required to assure optimal metabolism of substrate. Large changes in loading are likely to have considerable effects on process performance because of the time necessary for the biological population to adjust itself to the new situation (Carberry, 1983).

Factors which affect the settleability of activated sludge include septicity of the incoming wastewater, floc-loading rate of the activated sludge, plug-flow configuration of the aeration tank, supply rate of DO to the respiring micro-organisms, nutrients for the successful growth of the required bacteria, and denitirification in an anoxic zone at the inlet of the aeration tank. Two significant factors that influence the stability of activated sludge, but over which there is minimal control, are the climate and the incoming wastewater. An understanding of the effect of these factors, and their application in practice, will ensure the success of the process- provided that the design of the settlement tank is also correct. ASP also creates high solids loading and fluffy biological floc.

The oxygen uptake rate (OUR) for sludge, may give essential information about the condition of the sludge. Raw wastewater is oxidized to a suitably high oxygen concentration. Subsequently the oxidation is stopped, while the wastewater is still being stirred. A respiration rate for activated sludge of 20-40 g O_2/(kg VSS.h) signifies that the sludge is activated (many living micro-organisms), and that sufficient substrate (organic matter) is present. A low respiration rate (5-10 g O_2/(kg VSS.h) may signify something else, for example that the sludge is poisoned, not easily degradable organic matter is present or the sludge has been stabilized (for example by aerobic sludge stabilization).

In rising sludge, the floc particles become detached from the main sludge blanket and rise to the surface of the clarifier causing a scum to form. This is mainly due to the process of denitrification but may also be associated with low mixed-liquor suspended solids (MLSS) concentration, high return rate, or excessive aeration. During biological foam, a stable foam can form on the surface of aeration lanes and clarifiers in a very short period of time. Microscopically, the floc may not appear to contain large numbers of filament, but due to the presence of surfactants or long-chain fatty acids large numbers of filaments accumulate at the air/sludge interface (Foot, 1992).

Sludge is an inevitable residue of WWTP. Though it can be considered as a replenishable natural resource in some cases, often, it is economically and environmentally an unwanted burden. Historically, water treatment plant sludge used to be discharged into the nearest watercourses or sewer systems, with little or no treatment. Now, this sludge cannot be disposed of in sanitary sewers, as this would have many adverse effects. Moreover, due to stringent effluent discharge standards, it cannot be disposed of into the natural water bodies. Hence, it is very important to choose a suitable sludge treatment and disposal system, which is both economically and technically feasible. In order to achieve economical management of the sludge, it is important to reduce the quantity of sludge by increasing the solids concentration (Dharmappa, 1997). This is achieved in the WWTP by the Thickening method followed by sludge dewatering.

The large amount of waste sludge, constituting of refractory and non-biodegradable cellulose compounds, which is produced by this process leads to the difficulty of sludge disposal. In order to destroy the refractory structure of waste activated sludge and increase its biodegradability, a physio-chemical pretreatment method is commonly carried out to transform the particulate compounds contained in Waste Activated Sludge (WAS) into soluble compounds. While a thermal or a thermochemical pretreatment of sludge results in an increase in biodegradability, a thermal process consumes substantial amounts of energy in addition to chemical consumption. A chemical pretreatment method by dosing NaOH to hydrolyze the WAS is significantly effective for the solubilization of WAS, increase in soluble chemical oxygen demand concentration, and the increase in biodegradability. Chemical pretreatment such as alkaline hydrolysis converts the particulate fraction into soluble materials and this enhances the digestibility of the WAS. Alkaline hydrolysis could be applied in pretreating the WAS to destroy the complex structures and recover the organic matters contained in supernatant; also, alkaline hydrolysis could reduce the amount of WAS to save the cost for final sludge disposal (Chang, 2002).

Secondary sedimentation immediately follows biological treatment, and is required before any advanced treatment processes can occur. In secondary treatment, the effluent is sent to a sedimentation tank called here as the secondary clarifier which perform two important functions. It separates the mixed-liquor suspended solids from the treated wastewater, resulting in an effluent sufficiently clarifier to meet regulatory standards and to concentrate or thicken the return sludge to minimize the quantity of sludge that must be handled. This activated sludge conversion process is only effective if proper clarification or separation of the sludge from the liquid portion of the mixed liquor occurs. The secondary clarifier provides the environment whereby separation via gravity settling can take place. Unsettled sludge carries over the clarifier's effluent and could contaminate the receiving body of water (Drinan, 2001).

The traditional approach for analyzing clarifier design and performance is based on the application of the solids flux theory. This approach describes the settling process at steady-state operating conditions and satisfactorily predicts the thickening performance of full-scale clarifiers that are not limited by their capability to convey settled solids to the return activated sludge withdrawal point. There is a substantial dilution of the sludge as it goes out of the feeding well and travels towards the top of the sludge blanket. Therefore, the incoming MLSS concentration to the secondary clarifier does not equal with the concentration leaving the bioreactor but undergoes a significant dilution. This phenomenon can be mainly attributed to faster sludge settling and withdrawal from the bottom of clarifier (Giokasa, 2002).

Circular clarifiers are preferred, and asserted to be superior, by some consultants for any size and type plant. In this plant the shape of the clarifier is circular. However, studies have shown that well designed rectangular clarifiers can be expected to perform at least as well as well designed circular clarifiers of the same surface area. Carryover of suspended solids in clarifier can be due to several causes; floc shear due to high aeration power levels, poor clarifier hydraulics, high wastewater Total Dissolved Solid (TDS) concentration, low or high mixed liquor temperature, rapid change in mixed liquor temperature and low mixed liquor surface tension. High mixed liquor turbulence levels created by mechanical aerator can cause floc breakup that results in high effluent suspended solids. This problem can be solved by reducing the aeration basin power and/or by installing a flocculation zone between the aeration basin and the clarifier.

Mechanical disintegration on sewage sludge has a positive influence on various steps of sludge treatment. Depending on the type of application this can be achieved by the destruction of the sludge floc or by the disruption of the microorganism in the sludge. The destruction of filamentous flocs improves the settling properties of bulking sludge. Therefore, problems caused by scum, such as scum running off from secondary settling tanks and foaming in digesters, can be reduced. The disintegration of microorganisms leads to a release of organic substances, which are easily accessible to a subsequent biological degradation process. The disintegrated sludges can be used as a substrate either in aerobic or anaerobic processes. This leads to an improvement of biological degradation processes in wastewater and sludge treatment. The application of disintegration is especially useful for excess sludge because of its high content of microorganisms (Muller, 1999).

Return sludge is provided to supply microorganisms to the incoming wastewater. Enough return flow is needed to maintain the desired MLSS in the aeration tanks. The return sludge is withdrawn form the clarifier. The required flow rate is determined by the settling characteristics of the activated sludge. The settled sludge is drawn fast enough to prevent the sludge blanket from rising-a condition that may eventually lead to a solids washout from the clarifiers.

The excess load of pollution brought about by return flows will have a direct impact on the biological treatment. Monitoring the load per unit mass indicates that the biological treatment will undergo serious modifications depending on the percentage of return flows considered, if the biomass concentration is kept constant in the aeration tank (Grulois, 1993).

2.7.1 Sludge Dewatering

Pre-treatment processes have been developed in order to improve subsequent sludge treatment and disposal. Disintegration of sludge solids in the aqueous phase changes the sludge structure and solubilizes organic matter. Applied disintegration techniques available are mechanical, thermal, chemical and biological methods. For the improvement of stabilization, mechanical and ozone treatment as well as thermal treatment perform best. Dewatering can be enhanced by thermal and freeze/thaw treatment. All methods show positive effects in the reduction of the number of pathogens. Pre-treatment leads to secondary effects like the generation of recalcitrant compounds and odor, which is mainly a problem of thermal and ozone treatment (Muller, 2001).

Solid/liquid separation processes such as pressure filtration; centrifugation and thickening are important unit operations in the water, wastewater and chemical industries. Such dewatering operations are useful in that they allow efficient recovery of water and at the same time, produce particulate slurries and filter cakes at a high concentration of solids. This is vitally important to the cost and efficiency of many processes (Aziz, 1999).

Sludge dewatering can be defined as the physical operation intended to reduce the moisture content of sludge until it can be handled as a solid. Chemical conditioning is applied to destabilize the sludge particles and to significantly enhance the ease of which water is removed. Frequent and unpredictable changes as sludge particles' characteristics and concentration often occur in WWTP operations. These can easily result in a poorly dewatered sludge since the operator doesn't always adjust the chemical conditioner feed rate quickly and appropriately (Dentel, 1993).

Sludge dewatering is preceded by a conditioning operation to enhance water removal efficiency. In the conditioning operation, chemical coagulants or polymers are added to promote sludge particle aggregation for easier dewatering. Alternative conditioning method for sludge thermal treatment at temperatures up to 80°C was extensively investigated. Dewatering characteristics such as sludge capillary suction time and specific resistance to filtration, sludge viscosity and concentration of solid cakes play an important role. A good correlation between capillary suction time and specific resistance to filtration was established for sludges from water treatment, but not for biological sludge. Cationic polymer exhibits the best enhancement on sludge moisture removal. The dewatering ability of sludge can be greatly enhanced by thermal treatment in conjunction with the use of polymers (Lin, 2001).

Most types of sludge produced at a sewage treatment works can be de-watered to a greater or lesser degree. However, this will almost invariably require the use of conditioning agents, which in turn will affect the treatment costs. Two points need to be emphasized. Firstly, the degree to which the sludge is de-watered may well affect the disposal of the sludge. For example, press cake cannot readily be disposed of to agricultural land. Secondly, de-watering produces a liquid fraction with a BOD, which can at times be quite significant. These liquors must be returned to the works inlet for treatment and it is essential that an allowance is made for the organic load that they will produce. The digestion of sludges has two objectives: to stabilize the solids so that they do not become objectionable on storage or when applied to agricultural land, and to reduce the level of pathogens and parasites in the sludge (Forster, 1985).

The dewatering of sludge using filter presses has been in common use for the past 80 years. The technology was mainly used in the United Kingdom for large WWTP especially where woolen grease was extracted from the sludge. It was also associated with the pre-drying of sludge prior to incineration. To meet the growing demand for drier cakes and better capital productivity the membrane filter press has been developed. With the introduction of improved polyelectrolytes, polymer dosing systems, insitu cloth washing and computerized control the dry solids content of the cake has become more consistent and for most wastewaters in excess of 30%. For many years the traditional method of conditioning sludge prior to dewatering in the filter press was by using such conditioning agents as lime, ferrous sulphate, ferric chloride, aluminium chlorohydrate or combination of these. There were some major drawbacks not least the fact that there is up to a 40% increase in bulk from the addition of the conditioning agents such as lime, together with the need to provide substantial handling and storage facilities of bulk chemicals. As a consequence the filter press lost ground against the more continuous machines such as belt presses and centrifuges (Lowe, 1992).

2.7.2 Thickening

Solid concentration is important in sludges. This is because concentrated biosolids saves storage space in a digester and allows for a longer digestion period for solids. In addition, highly concentrated biolsolids contains less water, which requires less energy to heat (incinerate). The proportion of solids and water in liquid biosolids depends on the nature of the solids, on whether biosolids is from primary or secondary settling tanks, and on the frequency of removal from these tanks. Water contained in the biosolids particle exists in four phases, which are free water, colloidal water, intercellular water and capillary water. Free or bulk, water is not associated with and not influenced by suspended solids; it can be easily separated and removed from biosolids by gravity. To remove colloidal and capillary water, biosolids must be chemically conditioned first and then mechanical methods, such as centrifugation or belt presses, are used to remove the water. Intracellular water is much more difficult to remove. For intracellular water to be separated from the biosolids particle, the cell structure must first be broken. This is usually accomplished by thermal treatment. Basically thermal treatment is accomplished with either direct or indirect drying.

Thickening is a process aiming at reducing sludge volumes up to four times. Both undigested and digested sludges are subjected to thickening but probably, the most cost effective single process in sludge treatment is gravity thickening of raw sludge since volume reduction has such a profound effect on downstream processing costs, and obviously on transport (Katsire, 1998).

Gravity thickening of sludge involves a significant period of anaerobic storage. During this period part of the sludge may degrade, increasing the quantity of dissolved and fine suspended matter in the interstitial liquor. Some of this liquor will be returned from the top of the thickener to the head of the treatment works, and it may add a significant load to the biological oxidation stage. Also, the filtration characteristics of the sludge may deteriorate during the thickening process, to such an extent that any benefit gained by the additional thickness of the feed to a mechanical dewatering process might be offset by additional chemical requirements to condition the stale sludge (Carberry, 1983).

2.7.3 Centrifugation

Centrifugation has the advantage of producing a cake product that is more consistent and less likely to generate odors. Moreover, centrifugation has the additional advantage of requiring less space than that required for other types of dewatering equipment. The major disadvantage associated with centrifugation is that it has higher power requirements, resulting higher power costs than the other mechanical dewatering methods. Two factors have been influential in resurgence of centrifugation. The development of improved polymers that create shear resistance floc allowing dryer cakes at low polymer dosage and development of high solids centrifuge technology that increases cake solids from the 20 to 22 % total solids range to a 25 to 30% total solid range.

Other advantages of centrifuges are low maintenance machines that provide years of nearly maintenance-free operation. Corrosion and erosion problems of the past have been reduced or eliminated by the use of durable construction materials such as stainless steel, carbide and 480 Urethane. Along with the advantage of being a totally enclosed system to reduce odors, centrifuges offer the additional advantage of containing vapors and aerosols, significantly improving the work environment. The centrifuge's self-containment system allows the area around the centrifuge to remain free of biosolids and liquids. They are also equipped with automatic controls, which allow these machines to run virtually unattended, resulting in minimal operator attention, which, in turn, reduces the number of operators required to operate the machine. The unit processes that are most often used for dewatering biosolids are: vacuum filtration, pressure filtration, centrifugation, and drying bed (Eckenfelder, 1998).

There are four types of centrifuges distinguishable by the range of throughput normally obtained, the solids concentration that can be handled, and by the centrifugal force developed. These four basic types are the basket, tubular-bowl, disc-bowl, and Solid-Bowl Centrifuge (SBC). In this plant only the solid-bowl type is used here. SBC are capable of dewatering or separating out any solid for many liquids, as long as the solids are heavier. In a typical solid-bowl centrifuge, the biosolids is fed through a stationary feed tube along the centerline of the bowl through a hub of the screw conveyor. The screw conveyor is mounted inside the conical bowl, rotating at 800 to 2,000 rpm. It rotates at a slightly lower speed than the bowl. Polymers used for biosolids conditioning also are injected into the centrifuge. Biosolids leaves the end of the feed tube, is accelerated, passes through the ports in the conveyor shaft, and is distributed to the periphery of the bowl. Solids settle through the liquid pool, are compacted by centrifugal force against the walls of the bowl, and are conveyed by the screw conveyor the drying area (beach) of the bowl. The beach area is an inclined section of the bowl where further dewatering occurs before the solids are discharged. Separated liquid is discharged continuously over adjustable weirs at the opposite end of the bowl where it is returned to the treatment plant for additional treatment (Spellman, 1997).

The many attributes of the (SBC) have prompted its acceptance in a wide spectrum of applications. In the waste treatment field, such machines are used for dewatering raw and digested sludges, thickening activated sludge, dewatering alum sludges from water treatment plants, classifying lime sludges from tertiary treatment, etc. SBC are definitely the most versatile of the many solids-liquid separation methods available today. The process variables in this machine are the sludge feed rate, the chemical feed rate, the type of chemical used, and the type, condition and history of the sludge being dewatered. (Vesilind, 1983)

There are two types of SBC, which is used in WWTP, which is the countercurrent flow and concurrent flow machines. In this WWTP the concurrent flow machine is used. In the concurrent centrifuge the feed biosolids is in the same directions as the flow through the bowl, so the solids are not disturbed by the incoming feed. Concurrent centrifuges are preferred because turbulence is lower (biosolids cake and filtrate pass through the bowl in a smooth, parallel fashion) in concurrent machines. Along with a reduction in turbulence, concurrent centrifuges provide better compaction and a drier cake product because the solids are conveyed over the entire length of the bowl (Spellman, 1997).